A SPACE DUST EXPERIMENT (SPADUS) FOR MEASUREMENT OF THE DISTRIBUTION OF MAN-MADE AND NATURAL DUST IN THE NEAR-EARTH SPACE FOR FLIGHT ON THE P91-1 ADVANCED RESEARCH AND GLOBAL OBSERVATION SATELLITE (ARGOS)

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LONG-TERM GOAL

The long-term goals are:

1. To develop instrumentation to measure for the first time individual dust particle velocities, trajectories, and spatial distributions with sufficient accuracy to identify their parent bodies from the orbital characteristics of the dust in near-Earth space;
2. To accurately measure particle mass distributions and dust fluxes, with immunity to possible intense backgrounds from radiation belts and/or intense magnetic fields;

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3. To develop, design and implement strategies for large-area sensors and sensor arrays to maximize data collection under conditions of low particle flux for future investigations of debris dust and of natural dust streams; and
4. To develop instrumentation providing very high time resolution (15 ms) charged particle (electrons, protons, heavier nuclei) energy distribution measurements within radiation belts.

SCIENTIFIC OBJECTIVES

In furtherance of the above objectives, with support from ONR Grant No. N00014-91-J-1716 (as well as NASA Grant NAGW-3078 and in-house funding from the Naval Research Laboratory and the Lockheed Space Sciences Laboratory), we have developed the SPADUS dust experiment. This instrument is to be launched into sun-synchronous orbit on the ARGOS P91-1 spacecraft in 1998. The prime scientific and engineering objectives of SPADUS are:

1. *Dust Particles*:
   a) To provide definitive measurements of the mass, flux, velocity and arrival directions of individual particles in near-Earth space, both for man-made particles (orbital debris) and for particles of natural origin. These measurements will be carried out over a particle size range in which there is little quantitative data available (particle diameter range ~ 2 to 200 microns);
   b) To provide a survey map based on the above three-dimensional measurements which will establish a baseline of the present near-Earth dust distribution and which will provide crucial data for evaluating current models of the debris hazards in near-Earth space;
   c) To determine the trajectory for each incident dust particle and thus to determine its likely origin as either man-made orbital debris (occupying primarily bound, near-circular orbits) or from natural sources, e.g., comets, asteroids, zodiacal cloud (occupying primarily unbound hyperbolic orbits);
   d) To search for transient dust flux increases from interplanetary dust stream encounters;
   e) To obtain direct data on orbital and size distribution for small debris particles;
   f) To characterize the spatial and temporal characteristics of orbital debris (debris streams);
   g) To obtain data which will permit determination of hazards to critical surfaces exposed to near-Earth space particulates in military and civil space programs; and
   h) To improve our understanding of the dynamical properties and evolution of small orbital debris particles.
2. *Energetic Charged Particles (Electrons, Protons, Heavier Nuclei)*:
   a) To obtain fast spectral snapshots of midlatitude Lighting-induced Electron Precipitation (LEP) events to better understand what is considered a major loss mechanism of the Earth's radiation belts. The flux from an individual event can be of the order of 10^5 cm^{-2} s^{-1} between 20 to 1000 keV. The structure of these events can be studied for the first time at a time resolution of 15 ms;

b) To provide the only monitoring of the charged particle environment on ARGOS for understanding backgrounds, enhanced solar flare particle fluxes, and anomalies; and

c) To obtain coordinated measurements with other ARGOS experiments. This is an opportunity to study the details of the aurora with the NRL state-of-the-art UV imagers and uniquely measure the size of LEP events with the high-sensitivity X-ray imager (USA experiment).

The SPADUS flight instrument is shown in Figure 1 and consists of: (1) a dust trajectory system consisting of two identical dust sensor arrays (D1 plane and D2 plane); (2) a digital electronics box containing the ANCILLARY DIAGNOSTIC SENSOR (ADS) charged-particle sensor system; and (3) the analog electronics box.

Upon the launch of ARGOS P91-1, the SPADUS instrumentation will be the first to provide accurate information concerning particle trajectories and temporal variations in the micro-particle environment in low-Earth orbit, a region of great practical importance for satellites and human activity in space.

APPROACH

The experimental approach used in the SPADUS experiment to achieve these objectives utilizes the polyvinylidene fluoride (PVDF) dust sensor developed at the University of Chicago under earlier NASA and ONR support. PVDF detectors have been incorporated in the DUCMA dust experiments on the VEGA missions to Comet Halley, in the (still-classified) ERIS mission, are included in the Cosmic Dust Analyzer experiment for the Cassini mission to Saturn, and are in the Dust Flux Monitor instrument for the STARDUST mission to Comet WILD-2.

RESULTS

During FY1997 the following tasks were accomplished:

1. Up until the time of the ARGOS spacecraft acoustic test (July 1997), the SPADUS instrument had been attached to the ARGOS spacecraft and had successfully undergone all Integrated Space Vehicle System tests;

2. The spacecraft acoustic test resulted in the destruction of the 16 D1 (front array) sensors. The 16 D2 sensors (back array) were unaffected by the acoustic test. The SPADUS instrument was removed from the spacecraft and the SPADUS trajectory box holding the 16 destroyed D1 sensors and 16 D2 sensors were removed from the SPADUS baseplate and transported back to the University of Chicago; and

3. During the period July 15-September 30, 1997, 21 new D1 sensors were constructed and tested. Sixteen of the 21 D1 sensors were selected for flight as the D1 array.

Acoustic re-test of the SPADUS trajectory box containing the new D1 sensors and earlier D2 sensors will take place early in FY98. Assuming the D1 and D2 sensors successfully pass this re-test, the trajectory box will be delivered to Boeing-North American (Seal Beach) and the complete SPADUS instrument will be re-integrated with the ARGOS spacecraft.

RELATED PROJECTS

The ONR SPADUS work is strongly related to other dust and debris projects within NASA, specifically:

1. The University of Chicago HIGH RATE DETECTOR (HRD) instrument for the NASA/ESA CASSINI Mission to Saturn was developed by the same scientific and technical staff responsible for SPADUS development (funded through JPL);
2. The SPADUS concept serves as the basis for the University of Chicago DUST FLUX MONITOR INSTRUMENT recently developed for NASA's STARDUST mission; and
3. The study of the small particle debris environment in near-Earth orbit has been identified as a high priority by NASA, ESA, and other government agencies concerned with space activities, as indicated by the following documents:
   a) European Space Agency, "Space Debris" SP-1109, Paris (1988);
   b) Reynolds and A.E. Potter, Jr., "Orbital Debris Research at NASA Johnson Space Center", Tech.Memo. 102155, National Aeronautics and Space Administration, Houston, TX (1989);
   c) National Security Council, "Report on Orbital Debris", Washington, DC (1989);
   d) Congress, General Accounting Office, "Space Program: Space Debris a Potential Threat to Space Station and Shuttle", Washington, DC (1990);
   e) Congress, Office of Technology Assessment, "Orbiting Debris: A Space Environmental Problem-Background Paper", OTA-BP-ISC-72, Washington, D.C., U.S. Gov't. Printing Office (1990); and
   f) "Preservation of Near-Earth Space for Future Generations", J.A. Simpson, Ed. Cambridge University Press, 1994.

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McKibben, R.B., et al., 1997. "Measurements of Micron-Scale Meteoroids and Orbital Debris With the Space Dust (SPADUS) Instrument on the Upcoming ARGOS P91-1 Mission," Proc. 2nd European Conf. on Space Debris, *ESOC*, Darmstadt, Germany, (ESA SP-393, May).